Appendix B

Radiological Control Documentation

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Radiological Control Documentation

The purpose of this appendix is to list all relevant radiation control regulatory requirements that the 30% design may have to meet. The requirements are based on five categories: (1) inhalation, (2) external radiation, (3) contamination, (4) air monitoring for airborne radioactivity, and (5) instrumentation. Under each of these categories are listed the regulatory requirements.

INHALATION Regulatory Requirements -10 CFR 835 and RCM (PRD-183, Rev. 6) Requirements

Table B-1. Inhalation Requirements

Section No.	Requirement
381 (p3-29)	Radiological Design Criteria: 1. For areas of .... occupancy is not continuous, the design objective shall be to maintain doses ALARA and below 20% of the occupational dose limits provided in Table 2-1 [see 835.1002(b)]. DOE recommends that design criteria be established to limit individual worker doses below 0.25 mrem per hour (500 mrem TEDE per year).
381 (p3-29)	Radiological Design Criteria: 2. For control of airborne radioactivity, the design objective shall be to avoid releases to the work place atmosphere under normal conditions and, under any conditions, to control inhalation by workers to levels that are ALARA. Confinement and ventilation shall normally be used [see 835.1002(c)].
381 (p3-29)	Radiological Design Criteria: 4. In justifying facility design and physical controls, optimization methods shall be used [see 835.1002(a)].
316 (p3-6)	1. The primary methods used to maintain individual internal doses ALARA shall be physical design features, such as confinement, ventilation, and remote handling [see 835.1001(a)]. The design objective shall be, under normal conditions, to avoid releases of radioactive material to the workplace atmosphere. The objective, under all conditions, shall be to control inhalation of radioactive material to levels that are ALARA [see 835.1002(c)].See Attachment 1 for additional ALARA requirements.

EXTERNAL (DIRECT) RADIATION Regulatory Requirements - 10 CFR 835 and RCM Requirements

Table B-2. External (direct) radiation requirements.

Section No.	Requirement
234 (p2-13)	Radiation Area: levels could result in an individual receiving > 0.005 rem in 1 hour at 30 cm [see 835.603(a)]
234 (p2-13)	High Radiation Area: Radiation levels could result in an individual receiving > 0.1 rem in 1hour at 30 cm [see 835.603(b)]
381 (p3-28)	Radiological Design Criteria: 1. For areas of .... occupancy is not continuous, the design objective shall be to maintain doses ALARA and below 20% of the occupational dose limits provided in Table 2-1 [see 835.1002(b)]. DOE recommends that design criteria be established to limit individual worker doses below 0.25 mrem per hour (500 mrem TEDE per year).
381 (p3-28)	Radiological Design Criteria: 4. In justifying facility design and physical controls, optimization methods shall be used [see 835.1002(a)].
	See Attachment 1 for ALARA requirements.

CONTAMINATION Regulatory Requirements - 10 CFR 835 and RCM Requirements

Table B-3. Contamination requirements.

Section No.	Requirement
235 (p2-14)	Contamination Area: Removable contamination levels (dpm/100 cm 2) > Table 2-2 values but ≤ 100 x Table 2-2 values [see 835.603(e)]
235 (p2-14)	High Contamination Area: Removable contamination levels (dpm/100 cm 2) > 100 x Table 2-2 values [see 835.603(f)]
235 (p2-14)	Fixed Contamination: Removable contamination levels < Table 2-2 removable values and total contamination levels > Table 2-2 total Values
235 (p2-14)	Soil Contamination Area: Contaminated soil not releasable in accordance with DOE 5400.5
235 (p2-14); 233 (p2-11)	1. A radiological buffer area shall be established for contamination control adjacent to any entrance to or exit from a contamination, high contamination, or airborne radioactivity area. The size of the radiological buffer area will be commensurate with the potential for the spread of contamination..
381 (p3-28)	Radiological Design Criteria: 3. For materials used in facility construction and modification, the design objective shall be to select materials that facilitate operations, maintenance, decontamination, and decommissioning [see 835.1002(d)]. Components will be selected to minimize the buildup of radioactivity. Control of surface contamination should be achieved by containment of radioactive material.
381 (p3-28)	Radiological Design Criteria: 4. In justifying facility design and physical controls, optimization methods shall be used [see 835.1002(a)].
381 (p3-28)	Radiological Design Criteria: 5. Support facilities should be provided for donning and removal of protective clothing and for personnel monitoring, when required.
381 (p3-28)	Radiological Design Criteria: 7. Existing facility designs that have office space and lunchrooms or eating areas within radiological areas, radioactive material areas, and radiological buffer areas require priority attention. Generally: a. Locating lunch rooms or eating areas, restrooms, drinking fountains, showers and similar facilities and devices is strongly discouraged within these areas b. Locating office spaces within these areas is strongly discouraged; to the extent that such space is essential to support radiological work, steps will be taken to preclude unnecessary occupancy.
421 (p4-7); Table 2-2 (p2-9)	Release to Controlled Areas (See Attachment 2).
422 (p4-8)	Release to Uncontrolled Areas: 1. DOE 5400.5 describes radiological criteria for releasing material to uncontrolled areas.
422 (p4-8)	Release to Uncontrolled Areas: 2. DOE 5400.5 will be used by the INEEL to obtain guidance on obtaining approvals on a case-by-case basis for releasing material that has been contaminated in depth or volume, such as activated material or smelted contaminated material.

Table B-3. (continued).

Section No.	Requirement
	a. DOE-ID: When referring to DOE 5400.5, Figure IV-1, use the following values for allowable total residual surface contamination (dpm/100 cm 2) for transuranics, I- 25, I-129, Ra-226, Ac-227, Ra-228, Th-228, Th-230, and Pa-231: (1) Average = 100 (2) Maximum = 300 (3) Removable = 20
463 (P4-15)	Decontamination: 2. Work preplanning should include consideration of the handling, temporary storage, and decontamination of materials, tools, and equipment. 3. Decontamination activities should be controlled to prevent the spread of contamination. 4. Water and steam are the preferred decontamination agents. Other cleaning agents should be selected based upon their effectiveness, hazardous properties, amount of waste generated, and ease of disposal.
	See Attachment 1 for ALARA requirements.

AIR MONITORING FOR AIRBORNE RADIOACTIVITY Regulatory Requirements - 10 CFR 835 and RCM Requirements

Table B-4. Air monitoring for airborne requirements.

Section No.	Requirement
235 (p2-14)	Airborne Radioactivity Area: Airborne concentrations (µCi/ml) above background: 1) are > the applicable DAC values; or 2) could result in an individual (w/o respirator) receiving an intake > 12 DAC-hrs in a week [see 835.603(d)]
555 (p5-18)	2. Air sampling equipment shall be used where an individual is likely to receive an annual exposure of 40 or more Derived Air Concentration (DAC) hours [see 835.403(a)(1)]. This intake generally represents a committed effective dose equivalent to an individual of approximately 100 mrem. Samples shall also be taken as necessary to characterize the hazard in areas where respiratory protection devices have been prescribed for protection against airborne radionuclides [see 835.403(a)(2)]. Air samples should be adequate to evaluate the concentrations of airborne radioactive materials at the individual's work locations.
	See Attachment 1 for ALARA requirements.

RADIATION CONTROL INSTRUMENTATION Regulatory Requirements - 10 CFR 835 and RCM Requirements

Table B-5. Radiation control instrumentation requirements.

Section No.	Requirement
555	1. Selection of air monitoring equipment should be based on the specific job being monitored. Air monitoring equipment includes portable and fixed air sampling equipment and continuous air monitors.
555	2. Air sampling equipment shall be used where an individual is likely to receive an annual exposure of 40 or more Derived Air Concentration (DAC) hours [see 835.403(a)(1)]. This intake generally represents a committed effective dose equivalent to an individual of approximately 100 mrem.
	3. Real-time (or continuous) air monitors are used to provide early warning to individuals of events that could lead to substantial unplanned exposures to airborne radioactivity. Such exposures could result from a breakdown of engineered controls or improper establishment of boundaries during work that creates airborne radioactivity. Real-time air monitoring shall be performed as necessary to detect and provide warning of airborne radioactivity concentrations that warrant immediate action to terminate inhalation of airborne radioactive material [see 835.403(b)].
	4. Air sampling equipment should be positioned to measure air concentrations to which individuals are exposed.
	5. Continuous air monitors should be capable of measuring 1 DAC when averaged over 8 hours (8 DAC-hours) under laboratory conditions.
	6. Real-time air monitoring equipment required by Article 555.3 should have alarm capability and sufficient sensitivity to alert individuals that immediate action is necessary to minimize or terminate inhalation exposures.
553	Area Radiation Monitors 1. In addition to the requirements and recommendations of Article 551, area radiation monitors (not to include area monitoring dosimeters discussed in Article 514) should be installed in frequently occupied locations with the potential for unexpected increases in dose rates and in remote locations where there is a need for local indication of dose rates prior to personnel entry.
	See Attachment 1 for ALARA requirements.

Appendix B - ATTACHMENT 1

MCP-91, ALARA Program And Implementation

Section 4.3.11

Project Managers and Radiological Support: Evaluate *optimization methods* (see def.) to ensure that occupational exposure to personnel is maintained as low as reasonably achievable (ALARA) when developing, documenting, and justifying facility design and physical controls.

Section 6

Optimization method. A documented method that describes how the factors affecting a protection decision, i.e., social, technical, economic, practical, and public policy, are assigned values to compare detriments and benefits.

Section 4.4 ALARA Design Review Process

4.4.1 Designers: Request radiological support early (by Title I design review) in the planning and design of new facilities or modification of existing facilities that are associated with handling, processing, or storage of radioactive material in accordance with 10 CFR 835 subpart K.

4.4.2 Designers/Radiological Support: Use form 431.01, Radiological Control Design Review or equivalent (containing at least the information on the form), to develop methods to implement ALARA processes into the early design and to support design modifications.

4.4.3 Radiological Support: Recommend ALARA measures to facilitate control of radiation exposure in controlled areas through facility and equipment design and administrative control.

4.4.4 Perform design reviews early in the design stage and throughout the entire work activity or work project using form 431.01 or equivalent (containing at least the information on the form).

4.4.4.1 Ensure that reasonable radiological considerations have been integrated into the design, the construction procedures, and the plans for decommissioning.

4.4.4.2 Evaluate, at a minimum, the primary methods used as physical design features, including:

A. general configuration of the facility

B. confinement and ventilation

C. remote handling and remote equipment

D. shielding

E. containment

F. decontamination capabilities.

4.4.7 Radiological Support/Managers: Use optimization methods for ALARA in developing and justifying facility design and physical controls during the design of new facilities or modification of existing facilities.

NOTE: *Step 4.4.7.1 design criteria is from 10 CFR 835.1002.(b) as a requirement for occupational personnel protection. It is not intended that routine continuous occupancy (2,000 hours/year) in radiation fields of 0.5 mrem/hr will be acceptable for workers at the INEEL.*

4.4.7.1 Ensure the design objective for controlling personnel exposures from external sources of radiation in areas of continuous occupancy (2,000 hours/year) is to maintain exposure levels below an average of 0.5 mrem per hour and as far below this average as is reasonably achievable (see RCM revision 3 Chapter 3, Part 8).

4.4.7.2 Ensure the design objectives for exposure rates for potential exposure to a radiological worker where occupancy differs from the above are as low as reasonably achievable (ALARA) and do not exceed 20 % of the applicable standards in 10 CFR 835.202."

4.4.7.3 Use the following guidelines as basic design criteria for new or modified facilities at the INEEL:

A. Full-time occupancy (an area where one may be expected to spend all or most of his/her workday)—use a design value of 0.1 mrem/hour as the design objective

B. Full-time access area (an area where access has no physical or administrative control on entry)—use a design value of 1.0/t mrem/hour in which "t" is the maximum average time in hours per day that the area is expected to be occupied by any one individual (at least hour).

4.4.7.4 When optimization studies prove the above would not be cost-beneficial, use higher dose rates and limit or control access to such areas.

4.4.7.5 Ensure the design objective for control of airborne radioactive materials under normal conditions is to avoid releases to the work place atmosphere and to control inhalation of such materials by workers to levels that are as low as reasonably achievable.

4.4.7.6 Ensure the design or modification of a facility and the selection of materials includes features that facilitate operations, maintenance, decontamination, and decommissioning.

4.4.8 Designers/Project Managers: Document radiological design reviews using form 431.01, Radiological Control Design Review, or equivalent (containing at least the information on the form) and records of temporary shield and portable ventilation installation and removal as a record with the design review package.

NOTE: *Decisions on the cost/benefit of reducing occupational dose involves judgments on the relative value of social, technical, and economic factors, considering the benefits arising out of the activity, potential detriments from the activity, and possible detriments from not performing the activity.*

4.4.10 Project Managers and Radiological Support: Use optimization techniques, including cost/benefit analysis, and a person rem value of $6,500.00 (or the value from 4.4.10.1–4.4.10.2 when approved for use) as a fundamental part of radiological design analysis and work review to establish ALARA Protective Measures (APM) to minimize radiological exposure (Appendix A provides examples.)

4.4.10.1 Use $6,500 as the Company value of person rem for determination of ALARA protective measures.

ATTACHMENT 2

Relevant Excerpts

RCM (PRD-183, Rev. 6), Section 421, Release to Controlled Areas

3. If ..... inaccessible surfaces are likely to be contaminated to levels in excess of the Table 2-2 values, then..... [see 835.1101(a)(2)] ..... If it is necessary to release the material or equipment from the radiological area, the material or equipment will be disassembled to the extent necessary to perform adequate surveys.

4. Removable contamination levels shall be less than Table 2-2 values prior to releasing material and equipment for unrestricted use in controlled areas [see 835.1101(a)(1) & (a)(2)].

6. Material and equipment with total or removable contamination levels exceeding Table 2-2 values may be moved on site from one radiological area to another if appropriate ......controls are established and implemented [see 835.1101(b)].

[see 835 Appendix D]

Table 2-1. Summary of Occupational Dose Limits

TYPE OF EXPOSURE	LIMIT
General Employee: Whole Body (internal + external) (TEDE) [see 835.202(a)(1)]	5 rem/year
General Employee: Lens of the Eye (external) [see 835.202(a)(3)]	15 rem/year
General Employee: Skin and extremities (external shallow dose) [see 835.202(a)(4)]	50 rem/year
General Employee: Any organ or tissue (other than lens of eye) (internal + external)[see 835.202(a)(2)]	50 rem/year
Declared Pregnant Worker: Embryo/Fetus (internal + external) [see 835.206(a)]	0.5rem/ gestation period

Table 2-2. Summary of Surface Contamination Values

RADIONUCLIDE	REMOVABLE (dpm/100 cm 2)	TOTAL (FIXED + REMOVABLE) (dpm/100 cm 2)
U-natural, U-235, U-238, and associated decay products	1,000 alpha	5,000 alpha
Transuranics, Ra-226, Ra-228, Th-230, Th-228, Pa-231, Ac-227, I-125, I-129	20	500
Th-nat, Th-232, Sr-90 6, Ra-223, Ra-224, U-232, I-126, I-131, I-133	200	1,000
Beta-gamma emitters (nuclides with decay modes other than alpha emission or spontaneous fission) except Sr-90 and others noted above. Includes mixed fission products containing Sr-90 4,7.	1,000 beta-gamma	5,000 beta-gamma
Tritium and tritiated compounds 5	10,000	NA

Notes

4. This category of radionuclides includes mixed fission products, including the Sr-90 which is present in them It does not apply to Sr-90 that has been separated from the other fission products or mixtures where the Sr-90 has been enriched [see 835 App. D, note 5].

5. Tritium contamination may diffuse into the volume or matrix of materials. Evaluation of surface contamination shall consider the extent to which such contamination may migrate to the surface in order to ensure the surface radioactivity value provided in this Table is not exceeded. Once this contamination migrates to the surface, it may be removable, not fixed; therefore, a "Total" value does not apply [see 835 App. D, note 6].

6. These values will be applied to total Sr-90/Y-90 activity resulting from processes involving the separation or purification of Sr-90.

7. These values will be applied to total Sr-90/Y-90 activity resulting from the presence of Sr-90 in mixed fission products.

Form 431.01 Radiological Control Design Review and Analysis Data

Radiological Engineer: Arlo D. Summers Date: October 16, 2000

Project Design Title: Staging, Storage, Sizing, and Treatment Facility (SSSTF) 30% Design

Project Manager: R. Lee Davison

Required form (or equivalent) for Title I design review of facility designs/modifications associated with handling, processing, or storage of radioactive material.

1. The original of this form shall be filed in the original project file. RadCon offices should retain a file copy as documentation of the review.

2. Use the checklist (yes/no/na) to identify issues that have been evaluated and comments to resolve concerns.

Yes	No	N/A		
☐	☐	☒	1.	Have optimization methods/cost-benefit analysis been applied to the facility design to ensure that occupational radiation exposure is maintained ALARA?
Comment: Radiation dose is small. Bounding analysis shows that maximum external dose will be less than 10 mrem for one hour exposure. The maximum internal dose will be less than 10 mrem for one hour exposure. This is for the worst case and not for normal operations.				
Yes	No	N/A		
☒	☐	☐	2.	Have sufficient engineering controls for radiation protection been incorporated into the design to prevent undue health and safety risks to plant personnel, the public and the environment?
Comment: The 10 mrem internal dose above is with a water spray system that decreases airborne acitivity by 1000.				
Yes	No	N/A		
☒	☐	☐	3.	Are radiological control concerns such as access/egress controls, contamination control barriers and containments, and radiation control boundaries addressed in the facility design?
Comment: Listed in EDF-1542 (3), Section 11.3.				
Yes	No	N/A		
☒	☐	☐	4.	Have specific control devices for reducing occupational radiation exposure such as, shielding, HEPA filtered hoods, glove-boxes, equipment containments, interlocks, barricades, shielded cells, installed decontamination systems, and remote operations been evaluated and used to the maximum extent practical?
Comment: The only specific control device is the water spray system (see above).				
Yes	No	N/A		
☐	☐	☒	5.	Does the ventilation system design provide sufficient capacity and proper flow pattern to prevent the spread and/or build-up of loose surface and airborne contamination?
Comment: Primary barrier is the water spray system. Ventilation is only for defense-in-depth and details will be determined in the 90% design.				
Yes	No	N/A		
☐	☒	☐	6.	Are sources of radiological or mixed waste generation and their disposal methods identified in the facility design?

Comment: This is only 30% design. This will specifically be addressed in the 90% design phase. Water from the decontamination facility may be disposed of in the mixing operations.				
Yes ☒	No ☐	N/A ☐	7.	Does the radiological design of the facility comply with criteria established in DOE directives and standards, the INEEL Radiological Control Manual, and applicable federal codes?
Comment: For 30% design only.				
Yes ☐	No ☐	N/A ☒	8.	For modifications to an existing facility, will there be an increase in operations, maintenance, research, inspections, or decommissioning requirements involving the radiological control area(s)?
Comment: SSSTF is a new facility.				
Yes ☒	No ☐	N/A ☐	9.	Is fixed radiological monitoring instrumentation identified and adequate for the proposed facility design or modification?
Comment: A pit type system was evaluated. If an alternate design is chosen it will have to be re-evaluated.				
Yes ☒	No ☐	N/A ☐	10.	Are the change rooms and personnel decontamination facilities sufficient in size and in the proper locations?
Comment: Change rooms are in the stabalization building and the administration building. Personnel decontamination if needed will be done at INTEC.				
Yes ☒	No ☐	N/A ☐	11.	Have space requirements for anticipated operations, maintenance, production, research and decommissioning in radiological control areas been evaluated?
Comment: A pit type system was evaluated. If an alternate design is chosen it will have to be re-evaluated.				
Yes ☐	No ☐	N/A ☒	12.	For modification(s) to an existing facility, does the work involved making this modification have the potential to exceed ALARA review trigger levels?
Comment: SSSTF is a new facility.				
Yes ☐	No ☒	N/A ☐	13.	Will a new radiation source be created and if so, is there a potential that existing area does rates will increase?
Comment: Not with the pit type system. If an alternative system is used this will need to be re-evaluated. For example, if a Komar shredder is used, a buildup of contamination could occur that would impact radiation dose received during maintance.				
Yes ☒	No ☐	N/A ☐	14.	Review previous similar jobs, designs and processes with similar hazards. Are controls compatible?
Comment: Based on trips to similar facilities at Hanford and Arlington, Oregon.				

Internal Radiation Dose Analysis

Waste Stream	Radio-nuclide	Specific Activity (pCi / g)	Specific Activity (nCi / g)	Class	ALI (MBq) EPA FGR11	DAC (micro Ci per cubic cm) 10CFR835	Air Concentration Worker is Immersed In (micro Ci / cubic cm)	Committed Effective Dose Equivalent per Unit Intake Dose Conversion Factor (Sv/Bq) EPA FGR 11	Committed Effective Dose Equivalent (rem per 1hr exposure)	REMEDY Effective Dose (Internal) (rem per 1hr exposure)	Organ	REMEDY Organ Dose (rem per 1hr exposure)	Organ Dose Conversion Factor (Sv/Bq) EPA FGR11	Organ Dose Using Dose Conversion Factor (rem per 1hr exposure)
Borax-1	Cr-51	0.0377	3.77E-5	D	2000	2E-5	2.6E-12	2.95E-11	3.8E-10	1E-9				
				W	900	1E-5		7.08E-11	8.3E-10					
				Y	700	8E-6		9.03E-11	1.0E-9					
Borax-1	Sc-46	.0856	8.56E-5	D	--	--	5.8E-12	--	--	--		--		
				W	--	--		--	--					
				Y	9	1E-7		8.01E-9	2.1E-7					
CFA-4	K-40	23.1	2.31E-2	D	10	2E-7	1.6E-9	3.34E-9	1.3E-5	--		--		
				W	--	--		--	--					
				Y	--	--		--	--					
Borax-1	Mn-54	0.0377	3.77E-5	D	30	4E-7	2.6E-12	1.42E-9	1.4E-8					
				W	30	3E-7		1.81E-9	1.8E-8					
				Y	--	--			--					
Borax-1	Co-58	0.0282	2.82E-5	D	--	--	1.9E-12	--	--					
				W	40	5E-7		1.72E-9	1.3E-8					
				Y	30	3E-7		2.94E-9	2.8E-8					
Borax-1	Fe-59	0.0735	7.35E-5	D	10	1E-7	5.0E-12	4.00E-9	1.0E-7					
				W	20	2E-7		3.30E-9	1.0E-7					
				Y	--	--		--	--					
Borax-1	Co-60	2000	2	D	--	--	1.4E-7	--	--	3.7E-2				
				W	6	7E-8		8.94E-9	5.4E-3					
				Y	1	1E-8		5.91E-8	4.3E-2					
Borax-1	Zn-65	0.0773		D	--	--	5.3E-12	--	--					
				W	--	--		--	--					
				Y	10	1E-7		5.51E-9	1.5E-7					
CPP-92	Sr-90	10800	10.8	D	0.7	8E-9	7.3E-7	6.47E-8	0.21	0.21				
				W	--	--		--	--					
				Y	0.1	2E-9		3.51E-7	0.64					
Borax-1	Zr-95	0.0751		D	5	6E-8	5.1E-12	6.39E-9	1.4E-7					
				W	10	2E-7		4.29E-9	5.5E-8					
				Y	10	1E-7		6.31E-9	1.6E-7					
ARA-25	Nb-95	0.0899	8.99E-5	D	--	--	6.1E-12	--	--					
				W	50	5E-7		1.29E-9	3.9E-8					

Waste Stream	Radio-nuclide	Specific Activity (pCi / g)	Specific Activity (nCi / g)	Class	ALI (MBq) EPA FGR11	DAC (micro Ci per cubic cm) 10CFR835	Air Concentration Worker is Immersed In (micro Ci / cubic cm)	Committed Effective Dose Equivalent per Unit Intake Dose Conversion Factor (Sv/Bq) EPA FGR 11	Committed Effective Dose Equivalent (rem per 1hr exposure)	REMEDY Effective Dose (Internal) (rem per 1hr exposure)	Organ	REMEDY Organ Dose (rem per 1hr exposure)	Organ Dose Conversion Factor (Sv/Bq) EPA FGR11	Organ Dose Using Dose Conversion Factor (rem per 1hr exposure)
				Y	40	5E-7		1.57E-9	3.8E-8					
Borax-1	Ru-103	0.0247	2.47E-5	D	60	7E-7	1.7E-12	8.24E-10	6.0E-9					
				W	40	4E-7		1.75E-9	1.5E-8					
				Y	20	3E-7		2.42E-9	1.4E-8					
Borax-1	Rh-106m	0.599	5.99E-4	D	900	1E-5	4.1E-11	5.77E-11	1.1E-8					
				W	1000	1E-5		4.51E-11	9.2E-9					
				Y	1000	1E-5		4.84E-11	9.9E-9					
ARA-12	Ag-108m	67.2	6.72E-2	D	7	8E-8	4.6E-9	8.14E-9	2.2E-8	--		--		
				W	9	1E-7		6.84E-9	1.4E-4					
				Y	0.9	1E-8		7.66E-8	1.6E-3					
Borax-1	Ag-110m	0.0492	4.92E-5	D	5	6E-8	3.3E-12	1.07E-8	1.5E-7					
				W	7	8E-8		8.34E-9	1.2E-7					
				Y	3	4E-8		2.17E-8	2.7E-2					
Borax-1	Sb-124	0.00705	7.05E-6	D	30	4E-7	4.8E-13	1.50E-9	2.7E-8	--		--		
				W	9	1E-7		6.8E-9	1.5E-8					
				Y	--	--		--	--					
CPP-92	Sb-125	13	1.3E-2	D	90	1E-6	8.8E-10	5.75E-10	2.3E-6					
				W	20	2E-7		3.30E-9	1.5E-5					
				Y	--	--		--	--					
CPP-92	I-129	3.1	3.1E-3	D	0.3	4E-9	2.1E-10	4.69E-8	3.7E-5					
				W	--	--		--	--					
				Y	--	--		--	--					
ARA-25	Cs-134	33.2	3.32E-2	D	4	4E-8	2.3E-9	1.25E-8	1.4E-4	1.3E-4				
				W	--	--		--	--					
				Y	--	--		--	--					
ARA-25	Cs-137	12400	12.4	D	6	7E-8	8.4E-7	8.63E-9	3.1E-2	3.2E-2				
				W	--	--		--	--					
				Y	--	--		--	--					
Borax-1	Ce-141	0.0483	4.83E-5	D	--	--	3.3E-12	--	--					
				W	30	3E-7		2.25E-9	3.7E-8					
				Y	20	2E-7		2.42E-9	8.0E-13					
Borax-1	Ce-144	0.274	2.74E-4	D	--	--	1.9E-11	--	--					
				W	0.9	1E-8		5.84E-8	5.0E-6					
				Y	0.5	6E-9		1.01E-7	1.6E-10					

Waste Stream	Radio-nuclide	Specific Activity (pCi / g)	Specific Activity (nCi / g)	Class	ALI (MBq) EPA FGR11	DAC (micro Ci per cubic cm) 10CFR835	Air Concentration Worker is Immersed In (micro Ci / cubic cm)	Committed Effective Dose Equivalent per Unit Intake Dose Conversion Factor (Sv/Bq) EPA FGR 11	Committed Effective Dose Equivalent (rem per 1hr exposure)	REMEDY Effective Dose (Internal) (rem per 1hr exposure)	Organ	REMEDY Organ Dose (rem per 1hr exposure)	Organ Dose Conversion Factor (Sv/Bq) EPA FGR11	Organ Dose Using Dose Conversion Factor (rem per 1hr exposure)
ARA-25	Eu-152	4.93	4.93E-3	D	--	--	3.4E-10	--	--	9.0E-5				
				W	0.9	1E-8		5.97E-8	9.1E-5					
				Y	--	--		--	--					
Borax-1	Eu-154	0.305	3.05E-4	D	--	--	2.1E-11	--	--					
				W	0.7	8E-9		7.73E-8	7.1E-6					
				Y	--	--		--	--					
Borax-1 CFA-04	Eu-155	0.243	2.43E-4	D	--	--	1.7E-11	--	--					
				W	3	4E-8		1.12E-8	7.1E-7					
				Y	--	--		--	--					
Borax-1	Hf-181	0.0468	4.68E-5	D	6	7E-8	3.2E-12	4.17E-9	5.7E-8					
				W	20	2E-7		3.48E-9	5.6E-8					
				Y	--	--		--	--					
Borax-1	Ta-182	0.0683	6.83E-5	D	--	--	4.6E-12	--	--					
				W	10	1E-7		5.88E-9	1.4E-7					
				Y	5	6E-8		1.21E-8	2.3E-7					
Borax-1	Hg-203	0.0288	2.88E-5	D	50	5E-7	2.0E-12	1.10E-9	1.1E-8					
				W	40	5E-7		1.55E-9	1.2E-8					
				Y	--	--		--	--					
				Organic (D)	30	3E-7		1.98E-9	2.0E-8					
				Vapor (W)	30	3E-7		1.73E-9	1.7E-8					
ARA-25	Ra-226	44.6	4.46E-2	D	--	--	3.0E-9	--	--	3.1E-2				
				W	0.02	3E-10		2.32E-6	2.3E-2					
				Y	--	--		--	--					
CFA-4	Th-234	48	4.8E-2	D	--	--	3.3E-9	--	--	--		--		
				W	7	9E-8		8.04E-9	1.0E-4					
				Y	6	6E-8		9.47E-9	1.6E-4					
CFA-04	U-233	1.04 (U-233/234)	1.04E-3	D	0.04	5E-10	7.1E-11	7.53E-7	2.1E-4					
				W	0.03	3E-10		2.16E-6	7.7E-4					
				Y	0.001	2E-11		3.66E-5	6.5E-3					
CFA-4	U-234	22.6	2.26E-2	D	.05	5E-10	1.5E-9	7.37E-7	5.5E-3	0.24				
				W	.03	3E-10		2.13E-6	1.6E-2					
				Y	0.001	2E-11		3.58E-5	0.13					
ARA-25	U-235	2.72	2.72E-3	D	0.05	6E-10	1.8E-10	6.85E-7	5.1E-4	2.7E-2				

Waste Stream	Radio-nuclide	Specific Activity (pCi / g)	Specific Activity (nCi / g)	Class	ALI (MBq) EPA FGR11	DAC (micro Ci per cubic cm) 10CFR835	Air Concentration Worker is Immersed In (micro Ci / cubic cm)	Committed Effective Dose Equivalent per Unit Intake Dose Conversion Factor (Sv/Bq) EPA FGR 11	Committed Effective Dose Equivalent (rem per 1hr exposure)	REMEDY Effective Dose (Internal) (rem per 1hr exposure)	Organ	REMEDY Organ Dose (rem per 1hr exposure)	Organ Dose Conversion Factor (Sv/Bq) EPA FGR11	Organ Dose Using Dose Conversion Factor (rem per 1hr exposure)
				W	0.03	3E-10		1.97E-6	6.2E-4					
				Y	0.002	2E-11		3.32E-5	3.0E-2					
CFA-4	U-238	35	3.5E-2	D	0.05	6E-10	2.4E-9	6.62E-7	6.6E-3	0.34				
				W	0.03	3E-10		1.90E-6	2.3E-2					
				Y	0.002	2E-11		3.20E-5	0.38					
CPP-92	Np-237	0.15		D	--	--	1.0E-11	--	--					
				W	2E-4	2E-12		1.46E-4	7.3E-3					
				Y	--	--		--	--					
CPP-92	Pu-238	259	0.259	D	--	--	1.8E-8	--	--	--	--	--	--	--
				W	3E-4	3E-12		1.06E-4	9.5	10	Gonad	2.2	2.8E-5	2.2
											Breast	4.6E-6	1E-9	7.9E-5
											Lung	1.5	1.84E-5	1.5
											R Marrow	14	1.52E-4	12
											B Surface	180	1.9E-3	150
											Thyroid	3.7E-7	9.62E-10	7.6E-5
											Remainder	7.7	7.02E-5	5.6
				Y	7E-4	7E-12		7.79E-5	7.0	6.8	Gonad	.83	1.04E-5	0.82
											Breast	4.8E-6	4.4E-10	3.5E-5
											Lung	26	3.2E-4	25
											R Marrow	5.3	5.8E-5	4.6
											B Surface	66	7.25E-4	57
											Thyroid	1.9E-7	3.86E-10	3.1E-5
											Remainder	2.9	2.74E-5	2.2
CPP-92	Pu-239	24.7 (Pu-239/240)	2.47E-2(Pu-239/240)	D	--	--	1.7E-9	--		0.69				
				W	2E-4	2E-12		1.16E-4	0.99					
				Y	6E-4	6E-12		8.33E-5	0.71					
CPP-92	Pu-240	24.7 (Pu-239/240)	2.47E-2(Pu-239/240)	D	--	--	1.7E-9	--	--	1.1				
				W	2E-4	2E-12		1.16E-4	0.99					
				Y	6E-4	6E-12		8.33E-5	0.71					
CPP-92	Am-241	23.6	2.36E-2	D	--	--	1.6E-9	--	--	1.0				
				W	2E-4	3E-12		1.20E-4	0.64					
				Y	--	--		--	--					

Converting pCi/g to nCi/g

pCi/g * 1E-12Ci/pCi * nCi/1E-9Ci => 1E-3

pCi/g times 1E-3 gives nCi/g

Converting pCi/g(soil) To microCi/cubic cm(soil)

pCi/g(soil) * 1.7 g/cubic cm (soil density) * 1E-12 Ci/pCi * micro Ci/1E-6 Ci => 1.7E-6

pCi/g(soil) times 1.7E-6 gives microCi/cubic cm(soil)

Fraction Of Soil That Is Airborne Dust

4E-5 / hr

Ref.: DOE-HDBK-3010-94, page 5-7

Converting pCi/g(soil) To microCi/cubic cm (airborne dust)

pCi/g(soil) * 1.7E-6 * 4E-5 => microCi/cubic cm (airborne dust)

pCi/g(soil) * 6.8E-11 => microCi/cubic cm (airborne dust)

Internal Dose

Internal Radiation Dose = Radioactivity Inhaled During Exposure Time (Intake) * Dose Conversion Factor

Radioactivity Inhaled During Exposure Time (Bq) = Actual Airborne Concentration (microCi/cubic cm) * Volume of Air Breathed in During Exposure Time (cubic cm)

Example

Pu-238 (from waste stream CPP-92)

Actual Airborne Concentration = 1.8E-8 microCi/cubic cm

Exposure Time = 1 hr

Effective Dose Conversion Factor (Y) = 7.79E-5 Sv/Bq ref: FGR 11, EPA-520/1-88-020, 9/1988

Standard Man (ICRP 23) Breathes 20 l / min

Radioactivity Inhaled During Exposure Time (Bq) = (1.8E-8 microCi/cubic cm) * (20 l / min) * (ml / 1E-3 l) * (cubic cm / ml) * (1E-6 Ci / microCi) * ((3.7E10 dis / sec) / Ci) * (Bq / (dis / sec)) * (60 min / hr)

Radioactivity Inhaled During Exposure Time (Bq) = (1.8E-8 microCi/cubic cm) * (4.4E10 Bq-cubic cm / microCi-hr) = 800 Bq / hr

Radioactivity Inhaled During Exposure Time of One Hour = 800 Bq

Effective Dose (rem) = 800 Bq * 7.79E-5 Sv/Bq * 100 rem/Sv = 6.2 rem

During Exposure Time Of 1 hr => 6.2 rem

Effective Dose (rem) = (1.8E-8 microCi/cubic cm) * (4.4E10 Bq-cubic cm / microCi-hr) * (7.79E-5 Sv/Bq) * (100 rem/Sv) = 800 Bq / hr

Effective Dose (rem) = (1.8E-8 microCi/cubic cm) * (7.79E-5 Sv/Bq) * (4.4E10 Bq-cubic cm / microCi-hr-Sv) * (100 rem/Sv)

Effective Dose (rem) = (1.8E-8 microCi/cubic cm) * (7.79E-5 Sv/Bq) * (4.4E12 Bq-cubic cm-rem / microCi-hr-Sv) = 6.2 rem

External Radiation Dose Analysis

Waste Stream	Radio-nuclide	Specific Activity (pCi / g)	Half Life	Gamma Energy (MeV)	Probability of Decay	Activity in Roll-on / roll-off Container (Ci)	Microshield External Dose for One Hour Exposure (mrem)
Borax-1	Cr-51	0.0377	28d	0.32	0.09	1.6E-6	
Borax-1	Sc-46	.0856	84d	1.1	1.0	3.6E-6	
				0.89	1.0		
CFA-4	K-40	23.1	1.3E9y	1.5	0.11	9.7E-4	
Borax-1	Mn-54	0.0377	310d	0.84	1.0	1.6E-6	
Borax-1	Co-58	0.0282	71d	0.51	0.30	1.2E-6	
				0.81	1.0		
Borax-1	Fe-59	0.0735	45d	1.1	0.56	3.1E-6	
				1.3	0.44		
Borax-1	Co-60	2000	5.3y	1.2	1.0	8.4E-2	4.6
				1.3	1.0		
Borax-1	Zn-65	0.0773	244d	1.1	0.49	3.2E-6	
CPP-92	Sr-90	10800	29y	none		0.45	--
Borax-1	Zr-95	0.0751	64d	0.72	0.49	3.2E-6	
				0.76	0.49		
ARA-25	Nb-95	0.0899	35d	0.77	1.0	3.8E-6	
Borax-1	Ru-103	0.0247	39d	0.50	0.88	1.0E-6	
Borax-1	Rh-106m	0.599	2.2h	0.51	0.88	2.5E-5	
				0.74	0.41		
				1.1	0.25		
ARA-12	Ag-108m	67.2	130y	0.61	0.90	2.8E-3	9.2E-2
				0.72	0.90		
				0.43	0.89		
Borax-1	Ag-110m	0.0492	255d	0.66	0.96	2.1E-6	
				0.89	0.71		
				1.4	0.24		
Borax-1	Sb-124	0.00705	60d	0.603	0.97	3.0E-7	
				1.7	0.50		
				2.1	0.07		
CPP-92	Sb-125	13	2.8y	0.43	0.31	5.5E-4	
				0.60	0.24		
				0.63	0.11		
CPP-92	I-129	3.1	1.7E7y	0.04	0.09	1.3E-4	
ARA-25	Cs-134	33.2	2.1y	0.80	0.99	1.4E-3	4.6E-2
				0.61	0.98		
				0.57	0.23		
ARA-25	Cs-137	12400	30y	0.66	0.85	0.52	6.1
Borax-1	Ce-141	0.0483	33d	0.15	0.48	2.0E-6	
Borax-1	Ce-144	0.274	285d	0.13	0.11	1.2E-5	
ARA-25	Eu-152	4.93	12.7y	0.122	0.37	2.1E-4	4.8E-3
				0.344	0.27		
				1.4	0.22		

Waste Stream	Radio-nuclide	Specific Activity (pCi / g)	Half Life	Gamma Energy (MeV)	Probability of Decay	Activity in Roll-on / roll-off Container (Ci)	Microshield External Dose for One Hour Exposure (mrem)
Borax-1	Eu-154	0.305	8.7y	1.3	0.37	1.3E-5	
				0.72	0.21		
				0.88	0.12		
Borax-1 CFA-04	Eu-155	0.243	4.7y	0.12	0.20	1.0E-5	
				0.087	0.32		
Borax-1	Hf-181	0.0468	46d	0.48	0.81	2.0E-6	
				0.13	0.48		
				0.35	0.13		
Borax-1	Ta-182	0.0683	115d	1.1	0.34	2.9E-6	
				1.2	0.27		
				1.2	0.16		
Borax-1	Hg-203	0.0288	50d	0.28	0.77	1.2E-6	
ARA-25	Ra-226	44.6	1600y	0.186	0.04	1.9E-3	1.8E-4
CFA-4	Th-234	48	24d	neg.		2.0E-3	
CFA-04	U-233	1.04 (U-233/234)	1.6E5y	neg.		4.4E-5	
CFA-4	U-234	22.6	2.5E5y	neg.		9.5E-4	
ARA-25	U-235	2.72	7.1E8y	0.185	0.54	1.1E-4	
				0.143	0.11		
CFA-4	U-238	35	4.5E9y	neg.		1.5E-3	
CPP-92	Np-237	0.15	2.1E6y	neg.		6.3E-6	
CPP-92	Pu-238	259	86y	neg.		0.011	
CPP-92	Pu-239	24.7 (Pu-239/240)	24000y	neg.		1.0E-3	
CPP-92	Pu-240	24.7 (Pu-239/240)	6600y	neg.		1.0E-3	
CPP-92	Am-241	23.6	458y	neg.		9.9E-4	

Converting pCi / g (soil) to Ci in a Roll-on / Roll-off Container

Mass (g) of soil in a roll-on / roll-off container:

Soil density = 1.7 g / cm3 Ref.: RHH

1.7 g / cm3 (soil) * 5 ft * 8 ft * 22 ft * (cm3 / 3.53e-5 ft3) = 4.2E7 g soil

pCi / g (soil) * 4.2E7 g (soil) * (1E-12 Ci / pCi) => 4.2E-5

Multiply pCi / g (soil) by 4.2E-5 to obtain Ci in a Roll-on / roll-off Container

MicroShield v5.05 (5.05-00086)
Bechtel Idaho

Page : 1
DOS File: Case1
Run Date: October 19, 2000
Run Time: 11:08:08 AM
Duration: 00:00:34

File Ref: ________
Date: ________
By: ________
Checked: ________

Case Title: ARA-25 Cs137 0.52 Ci
Description: Roll-on/roll-off Container Full of Soil--No Shielding
Geometry: 13 - Rectangular Volume

Source Dimensions

Length	152.4 cm	5 ft 0.0 in
Width	243.84 cm	8 ft
Height	670.56 cm	22 ft 0.0 in

Dose Points

	X	Y	Z
# 1	182.88 cm	335.28 cm	121.92 cm
	6 ft	11 ft 0.0 in	4 ft

Shields

Shield Name	Dimension	Material	Density
Source	880.0 ft³	Concrete	1.7
Air Gap		Air	0.00122

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels	μCi/cm³	Bq/cm³
Ba-137m	4.9192e-001	1.8201e+010	1.9741e-002	7.3041e+002
Cs-137	5.2000e-001	1.9240e+010	2.0868e-002	7.7211e+002

Buildup
The material reference is : Source

Integration Parameters

X Direction	40
Y Direction	40
Z Direction	40

Results

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0045	1.889e+08	3.281e-04	3.430e-04	2.249e-04	2.351e-04
0.0318	3.768e+08	1.161e-01	1.426e-01	9.669e-04	1.188e-03
0.0322	6.952e+08	2.236e-01	2.762e-01	1.799e-03	2.223e-03
0.0364	2.530e+08	1.254e-01	1.656e-01	7.126e-04	9.410e-04
0.6616	1.638e+10	1.358e+03	3.146e+03	2.633e+00	6.099e+00
TOTALS:	1.789e+10	1.358e+03	3.147e+03	2.636e+00	6.104e+00

Contamination Area Analysis

Contamination Bounding Analysis

Smallest RCM Contamination Limits:

Contamination Area: > 20 dpm/100 cm2

High Contamination Area: > 100 * 20 dpm/100 cm2

CPP-92 Waste Stream radionuclides that the 20 dpm/100 cm^2 limit applies to

U-234 (5.1 pCi/g), U-235 (0.23 pCi/g), Pu-238 (259 pCi/g), Pu-239 (24.7 pCi/g), Pu-240 (24.7 pCi/g), Am-241 (23.6 pCi/g), I-129 (3.1 pCi/g), Np-237 (0.15 pCi/g)

Total Specific Activity: (5.1 + 0.23 + 259 + 24.7 + 24.7 + 23.6 + 3.1 + 0.15) pCi / g = 340 pCi / g

340 pCi / g (soil) * 1.7 g (soil) / cm3 * 1E-12 Ci / pCi * 3.7E10 dis / s-Ci * 60 s / min = 1.3E3 dis / min-cm3

[(100 * 20 dis / min-100 cm2) / (1.3E3 dis / min-cm3)] * in / 2.54 cm = 0.62 in

Thickness of soil (1.7 g / cm3) containing 340 pCi/g on a surface that would result in a High Contamination Area is 0.6 in.

A Different Approach

Actual Concentration = 1.8E-8 microCi / cm3 (see internal dose bounding analysis)

Assuming no water spray for dust suppressant.

[(100 * 20 dis / min-100 cm2) / (1.8E-8 microCi / cm3)] * (microCi / 1E-6 Ci) * (s-Ci / 3.7E10 dis) * (min / 60 s) * (in / 2.54 cm) * (ft / 12 in) = 16 ft

Therefore if all of the dust containing radioactivity in a volume 16 ft high settled out on the floor it would be a High Contamination Area.